

## PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-242570

(43)Date of publication of application : 11.09.1998

(51)Int.Cl.

H01S 3/18  
H01L 33/00

(21)Application number : 09-037908

(71)Applicant : TOSHIBA CORP

(22)Date of filing : 21.02.1997

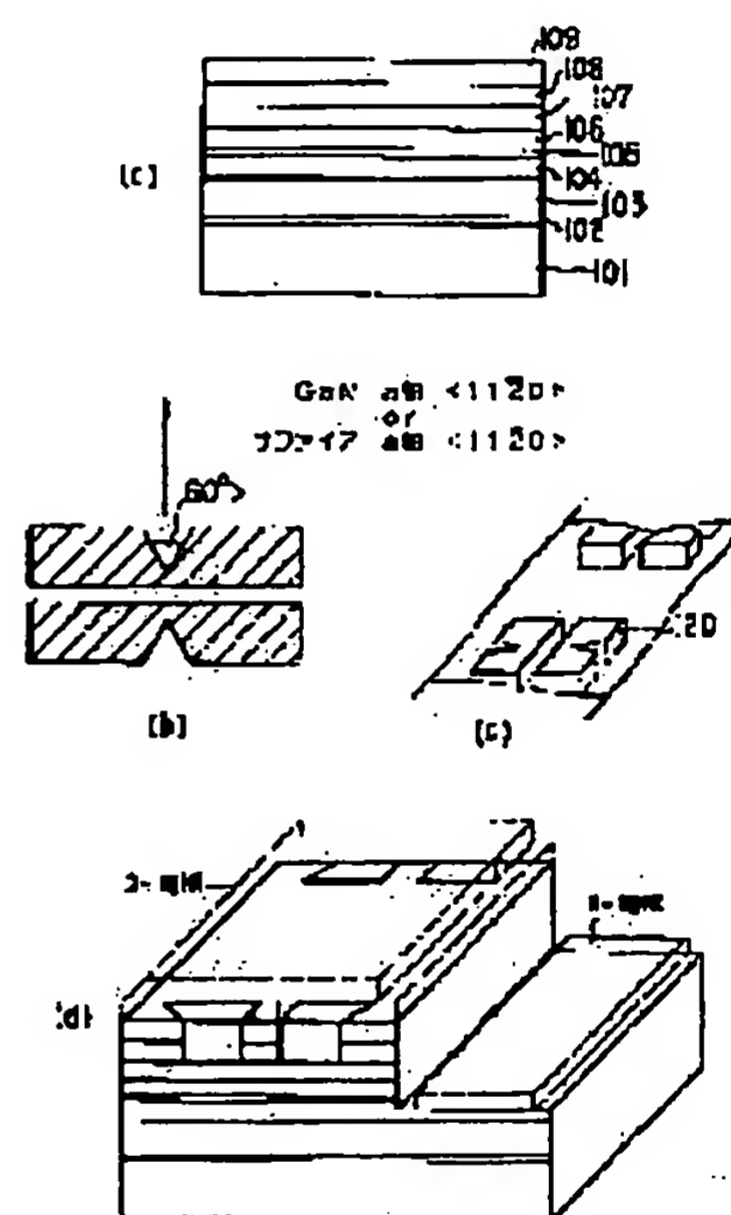
(72)Inventor : YAMAMOTO MASAHIRO

## (54) COMPOUND SEMICONDUCTOR LIGHT EMITTING ELEMENT AND ITS MANUFACTURE

(57)Abstract:

PROBLEM TO BE SOLVED: To element-isolate a GaN compound semiconductor laser having a base substrate of sapphire by cleavage with good controllability.

SOLUTION: Concerning to a manufacturing method for a compound semiconductor laser having a semiconductor laminated substrate wherein GaN compound semiconductors are laminated, an AlGaN cleavage auxiliary region layer 120 which has a cut line in a direction to be cleaved and does not function mainly for light confinement and current confinement is formed, on the said substrate after the formation of the laminated substrate. Following this, a selective etching for forming an n-side electrode is performed, and p-side and n-side electrodes are formed. Following this, the laminated substrate is cleaved and element isolation is performed, by splitting the cleavage auxiliary region layer 120 along the cut line.



BEST AVAILABLE COPY

## DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] Especially this invention is [0002] about the nitride system compound semiconductor element which aimed at amelioration of the cleavage technique with respect to the semi-conductor light emitting device, and its manufacture approach.

[Description of the Prior Art] In recent years, the compound semiconductor light emitting device containing a nitride attracts attention as the light source of short wavelength. Luminescence in the short wavelength field containing blue is possible for the nitride system compound containing GaN, and it is promising as a short wavelength luminescent material.

[0003] It is hard to process this kind of ingredient, especially the compound semiconductor layer which uses GaN as a main component conversely [ it is dramatically stable and ] therefore.

Moreover, the compound semiconductor of this system cannot usually use properties, such as cleavage, like GaAs and a GaP substrate, using sapphire as a substrate in many cases. For this reason, chip-izing etc. is dramatically difficult and it is difficult to create resonators, such as a laser diode which used cleavage like before.

[0004]

[Problem(s) to be Solved by the Invention] Thus, conventionally, in the nitride system compound semiconductor light emitting device containing GaN, the isolation by cleavage is difficult, and the end face of the compound semiconductor obtained by breaking a substrate forcibly had the problem that it did not function enough as a reflecting mirror.

[0005] Accomplishing this invention in consideration of the above-mentioned situation, the place made into the object is to offer the nitride system compound semiconductor light emitting device which made isolation by cleavage a controllability is good and possible, and its manufacture approach.

[0006]

[Means for Solving the Problem]

(Configuration) The main point of this invention is by introducing the original layer system containing aluminum by making isolation into a key objective at the semi-conductor laminated circuit board for constituting a nitride system compound semiconductor element to make isolation by cleavage possible.

[0007] That is, this invention is characterized by forming the cleavage auxiliary field which contains in the cleavage part of the flank of said laminated circuit board aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function in the compound semiconductor light emitting device which has the semi-conductor laminated circuit board which carried out the laminating of the nitride system compound semiconductor.

[0008] Moreover, this invention is set to the manufacture approach of a compound semiconductor light emitting device of having the semi-conductor laminated circuit board which carried out the laminating of the nitride system compound semiconductor. The process which becomes the maximum top face or the interior of said laminated circuit board from the layer containing aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function, and forms the cleavage auxiliary field which has a break in the direction which should be carried out cleavage, By breaking said cleavage auxiliary field along with said break, it is characterized by including the process which carries out cleavage of said laminated circuit board.

[0009] Here, the following are raised as a desirable embodiment of this invention.

- (1) The layer containing aluminum which constitutes a cleavage auxiliary field should be  $\text{In}_x \text{Al}_y \text{Ga}_z \text{N}_p \text{As}_q \text{Pr}_r$  ( $x+y+z=1$ ,  $0 < y$ ,  $p+q+r=1$ ).
- (2) The layer containing aluminum which constitutes a cleavage auxiliary field should be formed in the topmost part of a laminated circuit board.
- (3) The layer containing aluminum which constitutes a cleavage auxiliary field is in the middle of formation of a laminated circuit board, and be formed in the interior of this substrate.
- (4) Form the layer containing aluminum which constitutes a cleavage auxiliary field in 60 to 99% of thickness of the critical thickness by which a crack goes into the layer.

(5) Prepare the part from which it sees [ part ] in the layer containing aluminum which constitutes a cleavage auxiliary field from an electrode side, and width of face changes to it to the borderline of isolation.

(6) A laminated circuit board is that the laminated structure of a compound semiconductor is formed on silicon on sapphire.

(7) The break formed in a cleavage auxiliary field should be 60 or less degrees.

[0010] (Operation) GaN which usually carried out epitaxial growth on silicon on sapphire -- organic metal vapor growth (MOCVD) -- in the practical thickness field (for example, thickly a bid, with 15 microns) in law, it is in a crack free-lancer's (condition that a crack does not exist) condition. On the other hand, the thickness the layer containing aluminum, for example, AlGaN, can grow up to be by the crack free-lancer as the presentation of aluminum becomes large decreases.

[0011] although it can be checking that the thickness which can grow by the crack free-lancer changes also with growth conditions -- MOCVD -- there is no change in the critical thickness existing in the practical thickness field of law. And if the film is grown up more than this thickness, a crack will arise and a gash will go into the film. If a gash goes into the film, a substrate may be reached and a failure will be greatly brought to the function of a component. It is thought that this gash is produced when aluminum presentation enters and it compares with GaN, and physical parameters, such as a lattice constant, differ greatly.

[0012] this invention persons considered performing cleavage by using positively the gash which is generated in the layer containing aluminum and which originally is not desirable. However, the direction of the gash by the crack is irregular, and a direction to carry out cleavage cannot be chosen. Then, the break was intentionally prepared along the direction to carry out cleavage at the time of membrane formation of the layer containing not a gash but aluminum by the crack. And it found out that cleavage could be carried out in the direction which aimed at the semi-conductor laminated structure by controlling the value and thickness of a semi-conductor laminated structure and aluminum presentation the optimal.

[0013] Here, the layer containing aluminum for the cleavage introduced into a semi-conductor laminated circuit board, i.e., a cleavage auxiliary field, was a layer of the non-clad function which does not consider optical confinement and eye current \*\*\*\*\* as a main function, and even if were formed in the topmost part of a laminated circuit board and having been formed in the interior, the same cleavage effectiveness was acquired. Although the thickness of a cleavage auxiliary field needs to be less than critical thickness by which a crack goes into a laminated circuit board, the cleavage effectiveness mentioned above when not much thin is not acquired. According to the experiment of this invention persons, by setting the thickness of a cleavage auxiliary field as 60 to 99% of thickness of critical thickness showed that a controllability could improve cleavage.

[0014] Thus, in this invention, a controllability can improve a laminated circuit board cleavage by becoming the topmost part or the interior of a semi-conductor laminated circuit board from the layer containing aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function, and forming the cleavage auxiliary field which has a break in the direction which should be carried out cleavage. The reflection factor of the end face obtained by this cleavage was high enough, and became what fully functions as a reflecting mirror of a resonator. Therefore, according to this invention, it becomes possible from the former to perform good isolation of an end-face condition with a sufficient controllability. This effectiveness is [ as opposed to / especially / the semi-conductor laminated circuit board using sapphire without the property of cleavage like a semi-conductor etc. as a substrate substrate ] effective.

[0015]

[Embodiment of the Invention] Hereafter, the operation gestalt of a graphic display of the detail of this invention explains.

(1st operation gestalt) Drawing 1 is drawing for explaining the gallium nitride system compound semiconductor laser concerning the 1st operation gestalt of this invention.

[0016] Growth of each class was performed by the MOCVD method. First, as shown in drawing 1 (a), c-th page silicon on sapphire 101 is prepared, and a surface impurity is removed using heat phosphoric acid. Then, it moves in a reactor and temperature up is carried out to 1200 degrees. Then, substrate temperature grows up lowering and the GaN buffer layer 102 into 550 degrees. After

making it grow up for 3 minutes, substrate temperature is raised again, and it is SiH<sub>4</sub> at 1100 degrees. Gas grows up 2 micrometers of n mold GaN contact layers 103 with a sink.

[0017] Subsequently, 0.5 micrometers of n mold aluminum0.2 Ga0.8 N cladding layers 104 are grown up. Here, substrate temperature grows up the SQW layer (single quantum well layer) 105 of lowering and GaN/In0.1 Ga0.9 N/GaN into 800 degrees. At this time, it is SiH<sub>4</sub>. Supply has stopped. Then, substrate temperature is again made into 1100 degrees, and 0.2 micrometers of p mold aluminum0.2 Ga0.8 N cladding layers 106 are grown up.

[0018] Subsequently, Cp2 Mg grows up 0.3 micrometers of p mold AlGaIn layers 107 the same with a sink, and the p mold GaN layer 108 is grown up continuously. Furthermore, it is the flow rate of Cp2 Mg about 3 times Raising and p+ 0.1 micrometers grows the mold GaN contact layer 109.

[0019] Here, ejection patterning is performed for a substrate. a shaft orientations and the mask pattern of the crystal film serve as relation shown in drawing 1 (b) in the case of this patterning. Although it is an a-axis with the sapphire of the c-th page, it doubles with an a-axis, m shaft, etc. with a-th page sapphire. Here, a mask extracts and the hatching part in drawing is a pattern. Furthermore, a break is attached in consideration of the direction of cleavage. The include angle of this break is important, and if it is 60 or less degrees, the direction of cleavage will be stabilized by it.

[0020] RIBE (reactant ion beam etching) performs selective etching after patterning termination, and a part of AlGaIn layer 107 is exposed. And re-growth is performed at 1150 substrate temperature on the exposed AlGaIn layer 107, and as shown in drawing 1 (c), aluminum0.25Ga0.75N layer (cleavage auxiliary field) 120 are grown up. At this time, re-growth is prevented by attaching a suitable mask (SiO<sub>2</sub>, SiN, etc. being used) except the re-growth field. This mask may be used for the mask of said etching.

[0021] The description of this operation gestalt is in this re-growth. Under the present circumstances, the cleavage auxiliary field 120 is a layer aiming at making cleavage easy, and it is the description of this operation gestalt to make the distortion relaxation force of this cleavage auxiliary field layer 120 act on cleavage. The cleavage auxiliary field layer 120 does not necessarily need to cover the whole substrate, and has covered only the part needed for cleavage at worst. Installation of this partial AlGaIn cleavage auxiliary field layer 120 is the big description of this operation gestalt.

[0022] Mask material is removed after growth termination of the AlGaIn cleavage auxiliary field layer 120, and patterning for n lateral electrode formation is performed. And RIBE performs selective etching and the Part n type GaN layer 103 is exposed. Then, the basic structure of a component is completed by forming p lateral electrode on the contact layer 109, and forming n lateral electrode on the contact layer 103. In addition, patterning of the electrode is carried out so that it may dissociate for every component.

[0023] Subsequently, cleavage is performed along with patterning of an electrode. At this time, the cleavage of atomic layer order will not become possible without work of the AlGaIn cleavage auxiliary field layer 120 mentioned above. The end face by this cleavage had the high reflection factor, and was what fully functions as a reflecting mirror of a resonator. One of the obtained components is shown in drawing 1 (d). It is in the condition that the cleavage auxiliary field layer 120 which contains in the cleavage part of the flank of a semi-conductor laminated circuit board aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function remained.

[0024] Thus, according to this operation gestalt, along with the break of this layer 120, a controllability can improve a laminated circuit board cleavage by forming in the topmost part of the laminated circuit board of a GaN system compound semiconductor the AlGaIn cleavage auxiliary field layer 120 which has a break in part. For this reason, good isolation which used cleavage also in the semi-conductor light emitting device using sapphire as a substrate substrate could be performed, and 98% or more of high manufacture yield was able to be realized. Moreover, it was checked that an oscillation threshold carries out room temperature continuous oscillation of the laser diode obtained here by 40mA, and the life was 10000 hours or more.

[0025] (2nd operation gestalt) Drawing 2 is drawing for explaining the gallium nitride system compound semiconductor laser concerning the 2nd operation gestalt of this invention.

[0026] this operation gestalt -- growth -- MOCVD -- it carried out by law. First, as shown in drawing

2 (a), c-th page silicon on sapphire 201 is prepared, and a surface impurity is removed using heat phosphoric acid. Then, it moves in a reactor and temperature up is carried out to 1200 degrees. Then, substrate temperature grows up lowering and the GaN layer 202 into 550 degrees. After making it grow up for 3 minutes, substrate temperature is raised again, and it is SiH<sub>4</sub> at 1100 degrees. Gas grows up 2 micrometers of n mold GaN contact layers 203 with a sink.

[0027] Subsequently, 0.5 micrometers of n mold aluminum0.2 Ga0.8 N layers 204 are grown up. Here, substrate temperature grows up the SQW layer 205 of lowering and GaN/In0.1 Ga0.9 N/GaN into 800 degrees. At this time, it is SiH<sub>4</sub>. Supply is stopped. Substrate temperature is again made into 1100 degrees, and 0.2 micrometers of p mold aluminum0.2 Ga0.8 N layers 206 are grown up.

[0028] Subsequently, Cp2 Mg grows up 0.3 micrometers of p mold AlGaIn layers 207 the same with a sink, and the p mold GaN layer 208 is grown up continuously. Here, ejection and patterning are performed for a substrate. a shaft orientations and the mask pattern of the crystal film serve as relation shown in drawing 2 (b) in the case of this patterning. In addition, a mask extracts and the hatching part in drawing is a pattern. Furthermore, a break is attached in consideration of the direction of cleavage. This include angle is important, and if it is 60 or less degrees, the direction of cleavage will be stabilized by it. In addition, although the cleavage auxiliary field layer mentioned later is mostly formed in the whole surface with the mask of drawing 2 (b), it is also possible by preparing a mask pattern as shown in drawing 2 (c) to form a cleavage auxiliary field layer only in a required part.

[0029] Re-growth is performed after patterning termination. At this time, re-growth is prevented by attaching a suitable mask (SiO<sub>2</sub>, SiN, etc. being used) except the re-growth field. First, substrate temperature is made into 850 degrees and the InGaIn layer 209 is grown up. Furthermore, substrate temperature is made into 1150 degrees and it is p+. Mold aluminum0.25Ga0.75N layer (cleavage auxiliary field layer) 210 are grown up. At this time, Cp2 Mg is also poured simultaneously. Furthermore, the p mold GaN layer 211 is grown up, and it is the flow rate of Cp2 Mg Raising and p+ 0.1 micrometers grows the mold GaN layer 212. InGaIn at this time and re-growth of an AlGaIn layer are the descriptions of this operation gestalt. By adjusting the thickness of this InGaIn and AlGaIn, the substrate thickness whose cleavage becomes possible can be changed and this point is also the description of this operation gestalt.

[0030] Mask material is removed after growth termination and patterning for n lateral electrode formation is performed. And RIBE performs selective etching and the Part n type GaN contact layer 203 is exposed. Then, the basic configuration of a component is completed by constituting the electrode by the side of p and n. In addition, patterning of the electrode is carried out so that it may dissociate for every component.

[0031] Subsequently, cleavage is performed along with patterning of an electrode. At this time, the cleavage of atomic layer order will not become possible without work of the re-growth phase 210 mentioned above. The structure of the obtained component is shown in drawing 2 (e) except for the polar zone. It is in the condition of the topmost part of a GaN system semi-conductor laminated circuit board that the cleavage auxiliary field layer remained in the whole surface mostly.

[0032] Thus, also according to this operation gestalt, by forming the AlGaIn cleavage auxiliary field layer 210, the semi-conductor laminated circuit board could be separated by cleavage, and the same effectiveness as the 1st previous operation gestalt was acquired.

[0033] (Gestalt of the 3rd operation) Drawing 3 is the sectional view showing the manufacture approach of the GaN system compound semiconductor laser concerning the 3rd operation gestalt of this invention.

[0034] growth -- MBE (a molecular beam -- epitaxial) -- it carried out by law. First, as shown in drawing 3 (a), c-th page silicon on sapphire 301 is prepared, and a surface impurity is removed using heat phosphoric acid. Then, it moves in a growth chamber and temperature up is carried out to 800 degrees. At this time, it checks that a substrate front face is pure by RHEED (high energy electron beam reflected image).

[0035] Subsequently, substrate temperature grows up lowering and the GaN buffer layer 302 into 550 degrees. After making it grow up for 3 minutes, raise substrate temperature again, the shutter of Si cel is made to open at 750 degrees, and the shutter of Ga cel and an ECR plasma cell is opened simultaneously. Thereby, 2 micrometers of n mold GaN contact layers 303 are grown up.

Furthermore, 0.5 micrometers of n mold aluminum0.2 Ga0.8 N cladding layers 304 are grown up. Here, substrate temperature grows up the SQW layer 305 of lowering and GaN/In0.1 Ga0.9 N/GaN into 700 degrees. Supply of Si is stopped at this time. Substrate temperature is again made into 800 degrees, and 0.2 micrometers of p mold aluminum0.2 Ga0.8 N cladding layers 306 are grown up.

[0036] Subsequently, similarly 0.3 micrometers of p mold AlGaIn layers 307 are grown up, opening the shutter of Mg cel, and the p mold GaN layer 308 is grown up continuously. Furthermore, it is the flow rate of Mg Raising and p+ 0.1 micrometers grows the mold GaN contact layer 309.

[0037] Here, ejection and patterning are performed for a substrate. That is, it is SiO<sub>2</sub> to the part which serves as a break of a cleavage auxiliary field in consideration of the direction of cleavage (a broken line shows) as shown in drawing 3 (b). The masks 320, such as SiN, are formed.

[0038] Subsequently, re-growth is performed. At this time, the mask 320 has protected re-growth except the re-growth field. Substrate temperature is made into 800 degrees and aluminum0.25Ga0.75N layer 310 is grown up. It is one description of this operation gestalt that the layer 310 containing aluminum, such as AlGaIn, exists in the component topmost part here. As opposed to the maximum upper layer, subsequent cleavage can be made easy to the existing component structure by optimizing [ as opposed to / for the AlGaIn layer 310 / substrate thickness ] the thickness.

[0039] In addition, it is not necessary to necessarily form a cleavage auxiliary field layer the whole surface on a semi-conductor laminated circuit board, and as shown in drawing 4, it may be selectively formed only in a required part. Mask material is removed after growth termination of the AlGaIn layer 310, and patterning for n lateral electrode formation is performed. It \*\*, RIBE performs selective etching and the Part n type GaN contact layer 303 is exposed. Then, the basic configuration of a component is completed by constituting the electrode by the side of p and n. In addition, patterning of the electrode is carried out so that it may dissociate for every component.

[0040] Subsequently, cleavage is performed along with patterning of an electrode. At this time, the cleavage of atomic layer order will not become possible without work of the re-growth phase 310 mentioned above. The structure of the obtained component is shown in drawing 5 except for the polar zone.

[0041] The laser diode of this operation gestalt has the structure of having an AlGaIn layer, in a part of maximum top face of a component, and cleavage is easily possible for it by sticking a substrate on a seal after the dicing from a substrate flesh side. The manufacture yield was 98% or more, an oscillation threshold is 40mA and carrying out room temperature continuous oscillation was checked.

[0042] In addition, this invention is not limited to each operation gestalt mentioned above. Although the operation gestalt explained taking the case of GaN system compound semiconductor laser, it is applicable not only to this but other compound semiconductor laser. Furthermore, it is possible not only semiconductor laser but to apply to light emitting diode. Moreover, a substrate substrate is not restricted to sapphire and just grows a compound semiconductor layer. In addition, in the range which does not deviate from the summary of this invention, it can deform variously and can carry out.

[0043]

[Effect of the Invention] As explained above, according to this invention, a controllability can improve a laminated circuit board cleavage by becoming the topmost part or the interior of a semi-conductor laminated circuit board from the layer containing aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function, and forming the cleavage auxiliary field which has a break in the direction which should be carried out cleavage. Therefore, according to this invention, it becomes possible from the former to perform good isolation of an end-face condition with a sufficient controllability, and big effectiveness is demonstrated to manufacture of the semiconductor laser using sapphire without the property of cleavage etc. as a substrate substrate.

## CLAIMS

---

[Claim(s)]

[Claim 1] The compound semiconductor light emitting device characterized by forming the cleavage auxiliary field which contains in the cleavage part of the flank of said laminated circuit board aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function in the compound semiconductor light emitting device which has the semi-conductor laminated circuit board which carried out the laminating of the nitride system compound semiconductor.

[Claim 2] The manufacture approach of a compound semiconductor light emitting device of having the semi-conductor laminated circuit board which is characterized by providing the following and which carried out the laminating of the nitride system compound semiconductor The process which becomes the maximum top face or the interior of said laminated circuit board from the layer containing aluminum which does not consider optical confinement and eye current \*\*\*\*\* as a main function, and forms the cleavage auxiliary field which has a break in the direction which should be carried out cleavage The process which carries out cleavage of said laminated circuit board by breaking said cleavage auxiliary field along with said break

[Claim 3] The manufacture approach of a compound semiconductor light emitting device of having the semi-conductor laminated circuit board which is characterized by providing the following and which carried out the laminating of the nitride system compound semiconductor  $\text{In}_x\text{Al}_y\text{Ga}_z\text{N}_p\text{As}_q\text{Pr}$  which does not consider optical confinement and eye current \*\*\*\*\* as a main function at the topmost part of said laminated circuit board Process which consists of a layer ( $x+y+z=1$ ,  $0 < y$ ,  $p+q+r=1$ ), and forms the cleavage auxiliary field which has a break in the direction which should be carried out cleavage The process which carries out cleavage of said laminated circuit board by breaking said cleavage auxiliary field along with a break

[Claim 4] The manufacture approach of a compound semiconductor light emitting device of having the semi-conductor laminated circuit board which is characterized by providing the following and which carried out the laminating of the nitride system compound semiconductor  $\text{In}_x\text{Al}_y\text{Ga}_z\text{N}_p\text{As}_q\text{Pr}$  which does not consider optical confinement and eye current \*\*\*\*\* as a main function inside this substrate in the middle of formation of said laminated circuit board Process which consists of a layer ( $x+y+z=1$ ,  $0 < y$ ,  $p+q+r=1$ ), and forms the cleavage auxiliary field which has a break in the direction which should be carried out cleavage The process which carries out cleavage of said laminated circuit board by breaking said cleavage auxiliary field along with a break after formation of said laminated circuit board